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STUDIES ON THE SYSTEMATIC UPTAKE OF TOXIC PHOSPHORUS ESTERS BY PLANTS— PHYTOTOXIC EFFECTS OF SOIL APPLICATIONS OF THE ORGANOPHOSPHORUS INSECTICIDES MEVINPHOS AND METHYL DEMETON ON SELECTED PLANT SPECIES

ASSESSMENTS BRANCH
NON EXPLOSIVE MUNITIONS DIVISION

TECHNICAL REPORT AFATL-TR-70-82

AUGUST 1970

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EGLIN AIR FORCE BASE, FLORIDA

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STUDIES ON THE SYSTEMIC UPTAKE OF TOXIC PHOSPHORUS ESTERS BY PLANTS -

PHYTOTOXIC EFFECTS OF SOIL APPLICATIONS OF THE ORGANOPHOSPHORUS INSECTICIDES MEVINPHOS AND METHYL DEMETON ON SELECTED PLANT SPECIES

Alvin L. Young, Captain, USAF
Billy C. Wolverton

FOREWORD

This report was prepared by the Assessments Branch, Non-Explosives Munitions Division, Air Force Armament Laboratory, Eglin Air Force Base, Florida 32542, during the period September 1969 to September 1970. The USAF Project supporting the research was Exploratory Development Project 5066.

The statistical analyses were performed by Booz-Allen Applied Research, Inc. The laboratory determinations on the soil characteristics conducted by the Soils Department, University of Florida, Gainesville, Florida, are gratefully acknowledged.

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This report has been reviewed and is approved.

John E. Hicks

JOHN E. HICKS, Colonel, USAF
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ABSTRACT

Data relating the tolerance of agronomic plants to soils contaminated with high concentrations of organophosphorus insecticides may emphasize the need for decontaminating soils following accidental spillage. The insecticides 2-carbomethoxy-1-methylvinyl dimethyl phosphate (mevinphos) and a mixture of the two isomers O,O-dimethyl S-[2-(ethylthio) ethyl] phosphorothioate and O,O-dimethyl O-[2-(ethylthio)ethyl] phosphorothioate (methyl demeton) were soil applied to 15 economically important plants at the rate of 100, 200, 400, and 800 pounds active ingredient per acre. The separate statistical analysis of the several days (1, 3, 7, and 10) on which measurements (damage ratings) were taken indicated that the effects of damage were clearly manifested by the seventh day. By the seventh day the average observed damage caused by mevinphos (all plants averaged) was slight to moderate while damage caused by methyl demeton was moderate to heavy. The 15 plant species could be divided into eight groups on the basis of similar phytotoxic responses to the insecticides. The most susceptible plants to soil drench applications were oats, wheat, collards, tomatoes, and sorghum.

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INTRODUCTION

The growing interest in ultra-low volume, aerial insecticide application is a direct reflection of the many advantages it offers over conventional spraying techniques. With the increasing use of ultra-low volume applications of concentrated organophosphorus insecticides by both the Air Force Special Operations Force (SOF) and the Tactical Air Warfare Center (TAWC) in military and civic action programs, a need exists to evaluate possible absorption of these materials by crops (or other agronomically important plants) grown in the contaminated soil. Generally, the organophosphorus insecticides do not persist in the environment. Their effects are limited to the areas of application and are of relatively short duration. However, soils may be heavily contaminated by repetitive soil treatment, by accumulation of fall-out after spraying for insect control, or by accidental spillage.

In an earlier report by Wolverton et al (1), the morphological effects resulting from foliar applications of organophosphorus insecticides to 15 economically important plants were reported. The organophosphorus insecticides 2-carbomethoxy-1-methylvinyl dimethyl phosphate (mevinphos) and a mixture of O,O-dimethyl S-[2-(ethylthio) ethyl] phosphorothioate and O,O-dimethyl O-[2-(ethylthio) ethyl] phosphorothioate (methyl demeton) were applied to the plant foliage at rates of 5, 10, 20, and 40 pounds active ingredient per acre (lb ai/A). In this study the same plant species were grown under similar environmental conditions; however, mevinphos and methyl demeton were applied to the soil, as a soil drench, at rates of 100, 200, 400, and 800 lb ai/A.

Clore et al (2) have reported on the effects of high rates of chlorinated insecticide residues on the growth of crops. In general, they found that rates of 100 pounds per acre (lb/A) of 2,2-bis (p-chlorophenyl)-1,1,1-trichloroethane (DDT) were required to reduce the yield of crops such as rye, beans, and strawberries. Likewise, Boswell et al (3) found that applications of 15 lb/A 1,2,3,4,5,6-hexachlorocyclohexane (lindane) reduced the yield of beets, lettuce, and spinach. In a field study, Scopes (4) applied granular formulations of three organophosphorus insecticides to the soil at rates of 10, 50, and 250 ppm (calculated on the dry weight of soil to a depth of 100 mm). He found that the highest rate of insecticide significantly reduced the germination and growth of sugar beets. Furthermore, he observed that in the field plots containing 250 ppm insecticide, 95% of the weed population was held in check by O,O-diethyl O-2-pyrazinyl phosphorothioate (thionazin) and 81% by O,O-diethyl-S-(ethylthiomethyl) phosphorodithioate (phorate).

Most of the organophosphorus insecticides decompose in the soil rapidly enough that their residues disappear between crop seasons; however, MacPhee, Chishol, and MacEachern (5) have reported that 0,0-diethyl-0-p-nitrophenyl phosphorothioate persisted for five years under relatively dry soil conditions. Edwards (6) reported that the persistence of pesticides in the soil depended on many factors. The major factors were the pesticide itself, soil moisture, soil temperature, wind or air movement, cover crops, soil cultivation, method of application to the soil, formulation, and soil microorganisms. Available data published by the American Chemical Society (7) suggest that pesticides persist in soils that are higher in organic matter than in mineral (sand or clay) soils. Higher organic soils tend to assume a colloidal form which binds the residues tightly to the soil particles. Lichtenstein and Schulz (8) found that in a muck soil, which is about 50% organic matter, insecticide residues were bound to the soil particles to such an extent that they were less effective against insects than in a sandy soil. Crops, moreover, absorbed pesticides most readily from sandy soils and least readily from muck soils. From laboratory studies with mevinphos, Getzin and Chapman (9) concluded that absorption of mevinphos by soil depended primarily upon the organic matter content; amounts absorbed ranged from 0.031 gram mevinphos per gram soil (g/g) for a sand loam to 1.27 g/g for a peat soil.

Heath (10) noted that systemic insecticides (e.g., mevinphos and methyl demeton) penetrate cellular membranes and are translocated in the xylem or phloem to plant parts distinct from the point of application. Scopes (4) applied C^{14}-labelled phorate to the growth medium of field beans and showed that the radioactivity became centered at necrotic lesions formed on the margins of the leaves. He suggested that the lesions were caused by the damaging of a single or small groups of cells as a result of some cell abnormality or the rapid loss of water through peripheral stomata or guttation. The transpiration, enhanced by the initial damage, increased the accumulation of the insecticide at the site, thereby causing phytotoxicity spots. Hall (11) subjected tomato plants to foliar and soil-applied tetraethyl pyrophosphate (TEPP) and found that dilute solutions stimulated stem elongation and time of flowering. Stronger solutions of TEPP inhibited these growth accelerations. He also noted that young plants were much more severely affected by TEPP than mature plants.

Thus, data relating the tolerance of economically-important plants to soils contaminated with heavy concentrations of organophosphorus insecticides may be of value in dictating precautions to be followed for aerial applications and may emphasize the need for decontaminating soils following accidental insecticide spillage (and/or purposeful disposal of organophosphorus materials).

SECTION II

TEST PROCEDURES

MATERIALS AND METHODS

A 2x4x15 factorial experiment replicated four times was initiated on 2 March 1969. The organophosphorus insecticides 2-carbomethoxy-1-methylvinyl dimethyl phosphate (mevinphos) and a mixture of O,O-dimethyl S-[2-(ethylthio) ethyl] phosphorothioate and O,O-dimethyl O-[2-ethylthio) ethyl] phosphorothioate (methyl demeton) were applied to the soil at the rate of 100, 200, 400, and 800 pounds active ingredient per acre. Control plants received no insecticide application. The mevinphos was formulated from 100% Phosdrin (10.3 lb ai/gal) and the methyl demeton from 25.4% Meta-Systox-R (2.0 lb ai/gal). Fifteen plant species were selected for their economic and agronomic importance. Table I lists species and varieties used, number of seeds per pot, and the age of plants at time of treatment. Corn, sorghum, and ryegrass were planted one week after the other species because of their rapid growth. All plants were treated on the same day.

Plants were grown in a clear glass greenhouse with a minimum night temperature of 65°F and maximum day temperatures of 90-95°F. The soil used in this experiment was greenhouse potting soil. The physical and nutritional characteristics of the soil are described in Table II. All plants were grown in 4-inch plastic pots. The plants were fertilized with 15-15-15 liquid fertilizer twice prior to insecticide treatment. Only sprays containing chlorinated materials were used for insect control prior to treatment.

In order to prevent surface run-off and to insure saturation of all the soil in each pot at time of soil drench treatment, data were obtained on the water consumption and/or water loss from the soil surface for the 15 plant species during a 4-day period just prior to treatment. The water utilization values (in mls) listed in Table III were obtained by recording an initial "wet" weight and then each day determining the amount of water (1 g = 1 ml) needed to restore the pot to its original weight. Since growth would have occurred during the 4-day period, and hence the original pot weight would have changed, and additional 5-ml aliquot was added to the average water utilization value. Thus, the volume for the soil drench applications at all concentrations of insecticide was based on a value of 40 mls. The insecticides were applied at the rate of 100, 200, 400, and 800 lb ai/A. Further watering of the plants was withheld for a period of 24 hours. After that time all plants were differentially watered as needed.

TABLE I. THE COMMON NAME, SCIENTIFIC NAME, NUMBER OF PLANTS PER POT, AND THE AGE OF PLANT AT TIME OF TREATMENT FOR ALL SPECIES USED IN THE INSECTICIDE EXPERIMENT

COMMON NAME	SCIENTIFIC NAME	PLANTS/POT	AGE AT TREATMENT (WEEKS)
Big Bluestem	*Andropogon gerardi* Vitman	30	5
Peanuts	*Arachis hypogaea* L. var. Early Runner	3	5
Oats	*Avena sativa* L. var. Florida 500	10	5
Collard	*Brassica oleracea* L. var. Georgia Blue Stem	1	5
Common Bermudagrass	*Synodon dactylon* Richard (L.) Pers.	50	5
Cotton	*Gossypium hirsutum* L. var. Stoneville 213	3	5
Soybeans	*Glycine max* (L.) Merr. var. Hood	3	5
Morningglory	*Ipomoea hederacea* (L.) Jacq	6	5
Ryegrass	*Lolium temulentum* (L.) Darnel	100	4
Tomatoes	*Lycopersicon esculentum* Mill. var. Homestead	1	5
Pensacola Bahiagrass	*Paspalum notatum* Flugge. var. Saure Parodi	30	5
Beans	*Phaseolus vulgarus* L. var. Butterpea	3	5
Sorghum	*Sorghum vulgare* Pers. var. Mor-Su	3	4
Wheat	*Triticum vulgare* Vill. var. Barrt	10	5
Corn	*Zea mays* L. var. Coker 71	3	4

TABLE II. PHYSICAL AND NUTRITIONAL CHARACTERISTICS* OF THE SOIL USED FOR GROWING THE PLANTS FOR THE INSECTICIDE EXPERIMENT

COMPONENT	AMOUNT
Sand	79.1%
Silt	14.5%
Clay	6.4%
Organic Matter	3.9%
pH	6.7
P_2O_5	72 lb/A
K_2O	326 lb/A
M_gO	1,326 lb/A
CaO	4,049 lb/A
NO_3	Low

*As reported by the Soils Department, University of Florida, Gainesville, Florida

TABLE III. DAILY WATER CONSUMPTION AND/OR WATER LOSS (ml) BY PLANT FOLIAGE OR FROM SOIL SURFACE DURING A FOUR-DAY PERIOD PRIOR TO SOIL DRENCH APPLICATIONS OF ORGANOPHOSPHORUS INSECTICIDES

PLANT SPECIES	DAY 1	DAY 2	DAY 3	DAY 4	AVERAGE
Big Bluestem	26	16	34	22	25
Peanuts	26	23	37	26	28
Oats	41	38	59	48	47
Collard	27	25	34	30	29
Bermudagrass	28	19	31	26	26
Cotton	32	21	35	29	29
Soybeans	42	38	48	35	41
Morningglory	34	19	30	25	27
Ryegrass	48	37	69	59	53
Tomatoes	27	22	35	25	27
Bahiagrass	24	15	30	24	23
Beans	45	34	46	39	41
Sorghum	45	34	61	46	47
Wheat	40	39	61	44	46
Corn	38	31	54	37	40
Average	35	27	44	34	35

The amount of damage to the plants was assessed 1, 3, 7, and 10 days after treatment by using the following visual rating scale:

0 - No damage

1 - Slight damage

2 - Moderate damage

3 - Heavy damage

4 - Extreme damage

5 - Death of all plants in pot

To support the ratings, notes on the extent of morphological or physiological damage were recorded.

STATISTICAL ANALYSES

Analysis of variance techniques were used to examine the effects of the insecticides upon the various plant species. The results of the four days were analyzed separately because of lack of independence among days. Cochran's test was applied to the species variances to examine their uniformity. When heterogeneity was indicated, a variance stabilizing square root transformation $(x = x + 0.1)$ was used.

Treating each day separately, the main effects, the two-factor or first-order interactions, and the three-factor or second-order interactions were tested for significance. When significant differences in the main effects occurred, Duncan's new multiple-range test was employed to compare each treatment mean with every other treatment mean. All results were tested at the 0.05 level of significance. When the 0.05 level proved significant, the 0.01 and 0.001 levels were examined. The lowest level at which significance occurred was reported in the results.

A logarithmic transformation of the concentrations was made in order to obtain equal spacing. The variation caused by concentration strengths was then partitioned using orthogonal contrasts. This enabled determination of the type of trend (linear, quadratic, or cubic) present in the data. The slopes of the damage versus concentration graphs were examined to determine if the type of damage response was similar for each insecticide. These slopes were computed by the method of least squares.

The percentages of deaths among the plants, for the various main effect considerations, were tested for significance by applying chi-square tests to the proportions.

SECTION III

TEST RESULTS AND DISCUSSION

None of the control plants exhibited damage during the ten-day period following soil drench applications of organophosphate insecticides to the other plants. The treated plants exhibited varying degrees of damage that were attributed to the effects of species, insecticides, and levels of the insecticide concentrations.

Injurious effects of soil drench applications were noticeable 24 hours after treatment. This was particularly true for sorghum and wheat. Many species (e.g., peanuts and corn) required almost one week before showing significant insecticide damage especially after treatment with mevinphos. In general, damage to most plants consisted of a progressive wilting, a pronounced chlorosis, and the eventual destruction of the supporting tissue (stems or culms) resulting in death of the plant. For most broadleaves, and especially tomato, soybeans, and beans, the first damage symptoms were at the leaf margin. Generally, the lower leaves were damaged more severely than the upper leaves. The damage appeared as light-colored, circular, necrotic indentations with reddish-purple border regions. These spots tended to be interveinal and near the leaf margin, but eventually most of the leaf became necrotic. Their descriptions are in close agreement with those of Getzin and Chapman (9) following soil drench applications of mevinphos and demeton on pea plants and with Wolverton et al (1) following concentrated foliar sprays of mevinphos and methyl demeton on 15 plant species. Figure 1 shows organophosphate insecticide damage on tomato following a soil drench application of 400 lb ai/A methyl demeton.

The separate statistical analysis of the several days (1, 3, 7, and 10) on which measurements (damage ratings) were taken indicated that the effects of damage were clearly manifested by the seventh day. Therefore, the discussion of results will be confined to the analysis of the amount of damage occurring by the seventh day. However, the results of the measurements of each day were analyzed by the analyses of variance method and the F-ratios are summarized in Table IV.

The effects of the two insecticides on the amount of damage sustained by the plants were found to be significantly different at the 99.9% probability level. By the seventh day the average observed damage caused by mevinphos was slight to moderate (damage index 1.6) while the damage caused by methyl demeton was moderate to heavy (damage index 2.4). Similarly, the effects of the different concentration levels were found

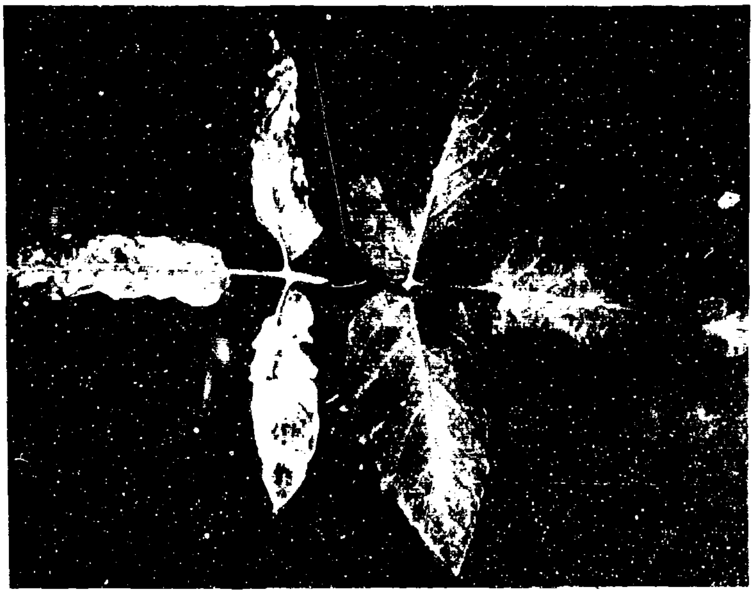

Figure 1. Organophosphate Insecticide Damage on Tomato Leaves One Week After a 400-lb ai/A Soil Drench Application of Methyl Demeton. The leaves on the right are from a control plant.

TABLE IV. SUMMARY OF RESULTS (ANALYSES OF VARIANCE) OF SOIL DRENCH APPLICATIONS OF MEVINPHOS AND METHYL DEMETON WITH DAMAGE RATINGS TAKEN 1, 3, 7, AND 10 DAYS AFTER TREATMENT

SOURCE OF VARIATION	F-RATIO†			
	DAY 1	DAY 3	DAY 7	DAY 10
Species	16.03**	25.26***	34.77***	50.57***
Insecticide	2.22	6.04*	279.56***	542.53***
Concentration	183.77***	509.64**	903.87***	983.17***
Species x Insecticide	5.95***	13.46***	15.75***	17.88***
Species x Concentration	2.81***	6.48***	9.14***	8.62***
Insecticide x Concentration	8.17***	8.67***	33.50***	41.32***
Species x Insecticide x Concentration	2.32***	4.89***	9.41***	11.49***

†Definition of F-Ratio: The variance of sample means is σ^2/n, where σ^2 is the variance of the individuals in the parent population and n is the sample size. This implies that means, where several are available, may be used to estimate σ^2. A second estimate of σ^2 is available from the individuals. The F statistic is the ratio of these two estimates of the variance:

$$\frac{\text{estimate of } \sigma^2 \text{ from means}}{\text{estimate of } \sigma^2 \text{ from individuals}}$$

If these two estimates are truly estimates of the same σ^2, then this ratio should be close to unity. As the size of the F statistic increases, there is more probability that two different populations are involved. The distribution of this statistic has been extensively tabled, and the tables are readily available.

*Indicates significance at the 95% probability level

**Indicates significance at the 99% probability level

***Indicates significance at the 99.9% probability level to be significantly different. The overall mean damage index for each concentration is shown in Table V. As would be expected, damage increased with an increase in concentration. In comparing the damage index for each soil drench concentration with its corresponding value for foliar application from the study by Wolverton et al (1), it appeared that a 20 to 1 relationship existed. For example, the plant damage resulting from a 400 lb ai/A soil drench application was similar to the damage resulting from a 20-lb ai/A foliar application. From these data, it seems feasible to suggest that the damage observed may have been a result of similar concentrations within the plant. The amount of insecticide translocated from the soil to the leaves may have been equal to that which entered the leaves from the foliar application. In elucidating the role of soil type in the relationship of plant damage to soil drench concentration, this laboratory (unpublished data) found that a soil drench application of 50 lb ai/A applied to plants growing in an acid-washed white sand media produced a damage rating of 2.5. This damage rating was comparable to that produced by the 400 lb ai/A application made to the greenhouse potting soil. These data clearly support the role of soil type (8) in influencing the amount of insecticide that a plant absorbs.

There was a significant difference (at the 99.9% probability level) in the reactions of the various species to the treatments they received. The overall mean damage indices for each species are presented in Table VI. Various species that reacted similarly were combined to form groups, and these groups and their overall mean damage are also presented in Table VI. Even though several species had similar overall means, their patterns of response to the different levels of concentration differed sufficiently enough so that they could not be grouped together. In the foliar study by Wolverton et al (1), the same 15 plant species could be divided, on the basis of similar response, into four groups (as compared to eight in this study). Whereas sorghum and corn responded similarly to foliar applications, they showed no similarity to soil drench applications. Furthermore, sorghum was the most susceptible species to soil drench application while soybean was the most susceptible species to foliar applications.

There were significant differences (Table IV) among the effects of the three-way interaction for species, insecticides, and concentrations. This indicated that plant species (e.g., cotton and tomato) did not respond in the same manner to the insecticides mevinphos and methyl demeton nor were their responses similar from one concentration level to the next concentration level. This type of three-way interaction is illustrated in Figure 2, which shows the trend in damage ratings for cotton and tomato seven days after treatment with four concentrations of soil drench applications of methyl demeton and mevinphos. Note that the two insecticides did not cause the same degree of plant response when applied at either 200 or 400 lb ai/A to cotton. However, similar responses were obtained when applied to tomato. Moreover, responses to soil drench applications of 100, 200, or 400 lb ai/A mevinphos were not the same with cotton as with tomato.

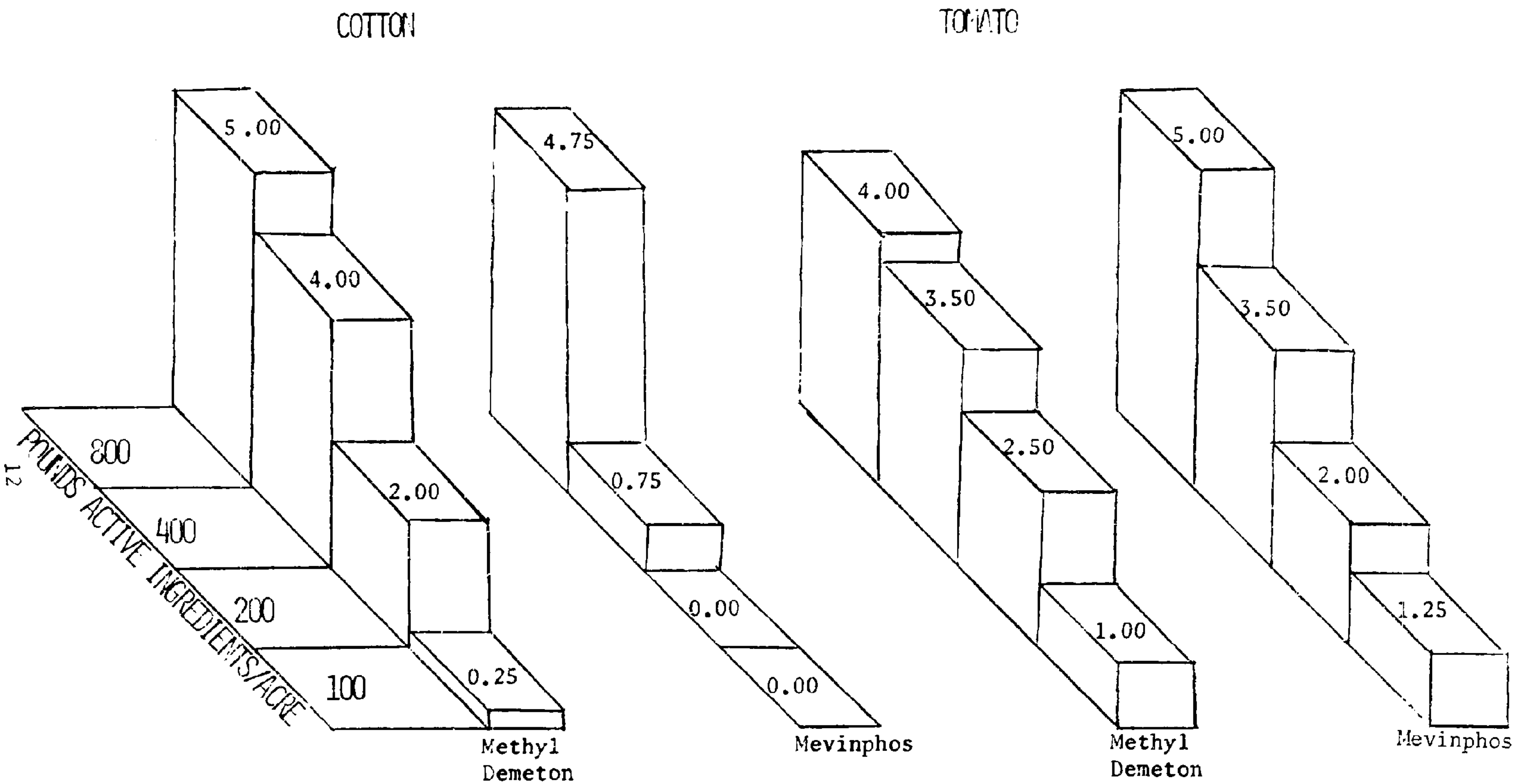

Figure 2. Response (Damage Ratings) of Cotton and Tomato, Seven Days After Treatment, to Soil Drench Applications of 100, 200, 400, and 800 lb ai/A Methyl Demeton and Mevinphos.

TABLE V. THE EFFECTS OF CONCENTRATION ON THE MEAN DAMAGE TO PLANTS ONE WEEK AFTER SOIL DRENCH APPLICATIONS OF ORGANOPHOSPHORUS INSECTICIDES

CONCENTRATION (lb ai/A)	DAMAGE INDEX	95% CONFIDENCE INTERVAL	
		LOWER	UPPER
100	0.67	0.54	0.80
200	1.42	1.22	1.64
400	2.75	2.51	3.00
800	4.09	3.87	4.32

TABLE VI. MEAN DAMAGE TO PLANTS ONE WEEK AFTER SOIL DRENCH APPLICATIONS OF THE ORGANOPHOSPHORUS INSECTICIDES MEVINPHOS AND METHYL DEMETON

GROUP	SPECIES	SPECIES DAMAGE INDEX	GROUP DAMAGE INDEX	95% CONFIDENCE INTERVAL	
				LOWER	UPPER
I	Oats	2.6			
	Wheat	2.2	2.4	2.1	2.8
II	Bahia	1.9			
	Bermuda	1.6			
	Bluestem	1.9			
	Rye	1.7	1.7	1.5	1.9
III	Soybeans	2.6			
	Beans	2.2	2.4	1.9	2.9
IV	Collards	2.5			
	Tomatoes	2.7	2.6	2.0	3.2
V	Morningglory	1.8			
	Cotton	1.4	1.6	1.1	2.2
VI	Peanuts	1.9	1.9	1.4	2.4
VII	Sorghum	3.2	3.2	2.4	4.0
VIII	Corn	1.0	1.0	0.6	1.7

The trends of the amount of plant damage caused by increasing the concentrations of soil drench applications of organophosphorus insecticides were tested statistically to determine which, if any, exhibited significance. Each of the groups of species demonstrated a highly significant response to logarithmic increase in concentration. Quadratic and cubic trends were at times also significant, but this was because of a lack of response until higher concentrations were applied or because death occurred at less than the highest concentration, or both. Table VII shows the lowest concentration at which appreciable damage was observed and the concentration level at which death occurred. Appreciable damage was considered to have occurred at those insecticide levels which caused at least a moderate amount of plant damage (damage index rating = 2.0).

The most susceptible plants to soil drench applications or organophosphorus insecticides were oats, wheat, collards, tomatoes, and sorghum. With the exception of sorghum, the other four species responded similarly to both mevinphos and methyl demeton. The susceptibility of sorghum to mevinphos and methyl demeton is shown in Figure 3. A soil drench application of 100 lb ai/A methyl demeton had no effect on the height of sorghum (and hence, on growth) while a similar rate of mevinphos not only affected growth, but was extremely detrimental to the vegetative material already present. The rapid drop in plant height was a result of destruction of the support tissue (culms). While the plants of Group V (morningglory and cotton) were not greatly affected by mevinphos, they were susceptible to methyl demeton (see Table VII).

To investigate the change in damage with the passage of time, the average damage index for each species group was plotted against days on which the measurements were taken (e.g., 1, 3, 7, and 10 days). The results indicated that there were no sizeable decreases in the amount of damage before the seventh day. An analysis of time after treatment (days) on the rate of damage change for the four concentration levels of each insecticide revealed that the rate of damage change was the same for each concentration level and each insecticide. These results are shown in Figure 4. Note that all the lines are approximately parallel. The rate-of-damage change steadily decreased from the first to the tenth day after treatment with either insecticide. Those plants treated with methyl demeton continued to show increasing damage through the tenth day, whereas those treated with mevinphos showed an increase in damage only through the seventh day.

The deaths caused by the two insecticides were analyzed for each group of plant species and also for each concentration level. These results are shown in Tables VIII and IX, respectively. The first of these two tables presents the percentage of deaths occurring within each species group during the entire experimental period. It can be noted that the percentage of deaths caused by methyl demeton was significantly greater than that caused by mevinphos for Groups II, III, VII, and VIII. Notice that the greatest number of deaths occurred when sorghum was soil drenched with methyl demeton. Fifty percent of all the soybeans and beans treated with methyl demeton were killed. Although Wolverton et al (1) did not observe plant death, they did note that soybeans receiving 40 lb ai/A methyl demeton were severely stunted and all new growth within a 30-day period showed damage symptoms. The data in Table IX can be summarized by noting that, while it required only 400 lb ai/A of methyl demeton to cause death, 800 lb ai/A of mevinphos were needed before death occurred. At both of these concentration levels, methyl demeton caused significantly more deaths than did mevinphos.

TABLE VII. CONCENTRATION LEVEL (LB ai/A) OF ONSET OF PLANT DAMAGE AND OF DEATH ATTRIBUTABLE TO SOIL DRENCHING WITH THE ORGANOPHOSPHORUS INSECTICIDES MEVINPHOS AND METHYL DEMETON

SPECIES GROUP	INSECTICIDE CONCENTRATION LEVEL (lb ai/A)			
	MEVINPHOS		METHYL DEMETON	
	ONSET*	DEATH	ONSET*	DEATH
I (Oats, Wheat)	200	800	200	800
II (Bahia, Bermuda, Bluestem, Rye)	800	---	300	800
III (Soybeans, Beans)	400	800	150	400
IV (Collards, Tomatoes)	200	800	200	800
V (Morningglory, Cotton)	500	800	200	500
VI (Peanuts)	800	---	300	800
VII (Sorghum)	100	800	150	200
VIII (Corn)	800	---	400	800

*The onset of plant damage was considered to have occurred at those insecticide levels which caused at least a moderate amount of damage (damage index rating = 2.0).

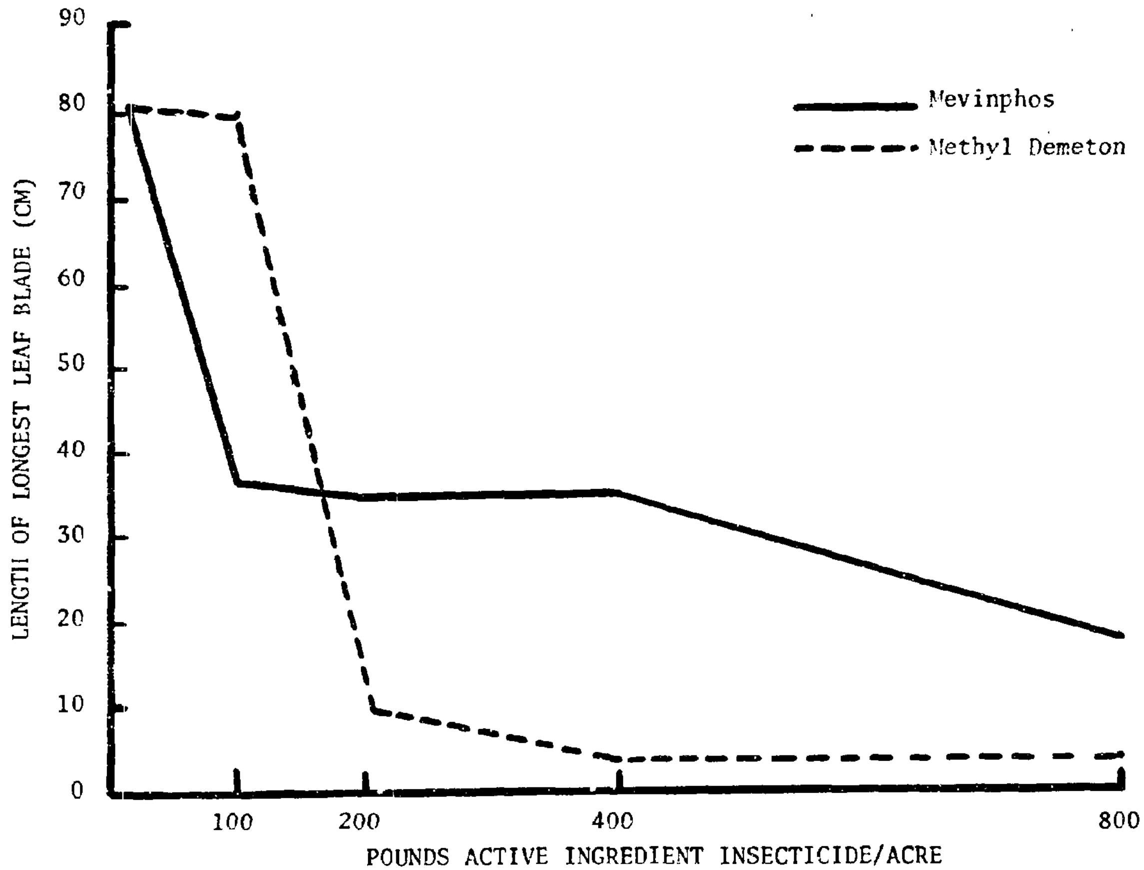

Figure 3. Height of Sorghum (cm) Ten Days After Soil Drench Applications of the Organophosphorus Insecticides Mevinphos and Methyl Demeton.

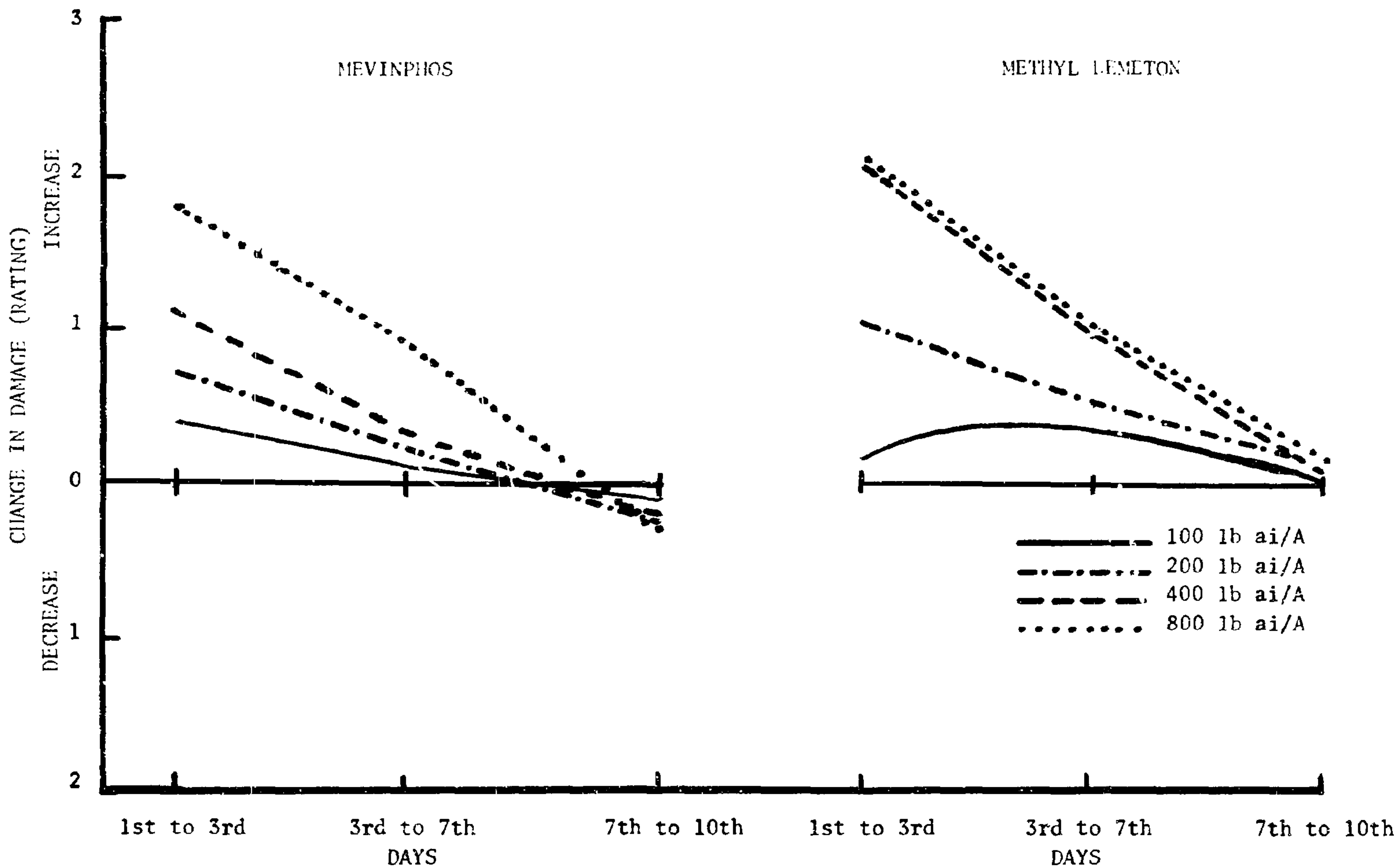

Figure 4. The Influence of Time After Treatment (days) on the Rate of Damage Change for Four Concentration Levels of Mevinphos and Methyl Demeton.

TABLE VIII. PERCENTAGES OF PLANT DEATHS (BY SPECIES) ATTRIBUTABLE TO SOIL DRENCH APPLICATIONS OF ORGANOPHOSPHORUS INSECTICIDES

SPECIES GROUP		MEVINPHOS	METHYL DEMETON	"t" TEST ** OF MEVINPHOS VERSUS METHYL DEMETON
I	(Oats, Wheat)	9.38*	21.88*	1.38
II	(Bahia, Bermuda, Bluestem, Rye)	0.00	18.75*	3.64*
III	(Soybeans, Beans)	12.50*	50.00*	3.24*
IV	(Collards, Tomatoes)	25.00*	34.38*	0.82
V	(Morningglory, Cotton)	21.80*	40.62*	1.62
VI	(Peanuts)	0.00	18.75*	2.57
VII	(Sorghum)	25.00*	68.75*	2.24*
VIII	(Corn)	0.00	25.00*	3.02*
	Aggregate	10.83*	32.08*	5.67*

*Indicates significance at the 95% probability level.

**A t-test investigates the probability that the value of a certain type of random variable or the difference between the values of two such random variables is greater than a critical number. This number is obtained from tables of the t-distribution. Its main use is with small samples.

TABLE IX. PERCENTAGES OF PLANT DEATHS ATTRIBUTABLE TO THE CONCENTRATIONS OF SOIL DRENCH APPLICATIONS OF ORGANOPHOSPHORUS INSECTICIDES

CONCENTRATION LEVEL	MEVINPHOS	METHYL DEMETON	"t" TEST** OF MEVINPHOS VERSUS METHYL DEMETON
100 lb ai/A	0.00	0.00	
200 lb ai/A	1.67	5.00	0.13
400 lb ai/A	3.33	35.00*	3.57*
800 lb ai/A	38.33*	88.33*	5.68*
Aggregate	10.83*	32.08*	5.67*

*Indicates significance at the 95% probability level.
**A t-test investigates the probability that the value of a certain type of random variable or the difference between the values of two such random variables is greater than a critical number. This number is obtained from tables of the t-distribution. Its main use is with small samples.

SECTION IV

SUMMARY AND CONCLUSIONS

Data relating tolerance of agronomic plants to soils contaminated with high concentrations of the organophosphorus insecticides mevinphos and methyl demeton are reported. In summary, it was found that:

1. Injurious effects of soil drench applications were noticeable 24 hours after treatment. The damage to most plants consisted of a progressive wilting, a pronounced chlorosis, and the eventual destruction of the supporting tissue (stems or culms) resulting in death of the plant.

2. The separate statistical analysis of the several days (1, 3, 7, and 10) on which measurements (damage ratings) were taken indicated that the effects of damage were clearly manifested by the seventh day. By the seventh day the average observed damage caused by mevinphos (all plants averaged) was slight to moderate (damage index rating of 1.6) while damage caused by methyl demeton was moderate to heavy (damage index rating of 2.4).

3. In comparing the damage index for each soil drench concentration with its corresponding value for foliar application, it appeared that a 20 to 1 relationship existed. For example, the plant damage resulting from a 400-lb ai/A soil drench application was similar to the damage resulting from a 20-lb ai/A foliar application. Soil type, however, has a significant influence upon this relationship.

4. The 15 plant species could be divided into eight groups on the basis of similar responses to the insecticide. These groups were:

   a. Group I - oats, wheat

   b. Group II - bahia, bermudagrass, big bluestem, and rye

   c. Group III - soybeans and beans

   d. Group IV - collards and tomatoes

   e. Group V - morningglory and cotton

   f. Group VI - peanuts

   g. Group VII - sorghum

   h. Group VIII - corn

5. Each of the groups of species demonstrated a highly significant response (as indicated by plant damage) to logarithmic increases in concentration of insecticide.

6. Plants that received applications of methyl demeton showed significantly more damage than those which received a comparable application of mevinphos.

7. The most susceptible plants to soil drench applications of organophosphorus insecticides were oats, wheat, collards, tomatoes, and sorghum. With the exception of sorghum, the other four species responded similarly to both mevinphos and methyl demeton. A soil drench application of 100 lb ai/A was extremely detrimental to sorghum, although it was not lethal.

8. In investigating the change in damage with passage of time, it was found that there were no sizeable decreases in the amount of damage before the seventh day. Those plants treated with methyl demeton continued to show damage through the tenth day, whereas those treated with mevinphos showed an increase in damage only through the seventh day.

9. The percentages of plant death occurring within a species was significantly greater with methyl demeton than with mevinphos. The greatest number (69%) of deaths occurred when sorghum was soil drenched with methyl demeton. Data on the concentration levels required to cause plant death could be summarized by noting that while it required only 400 lb ai/A of methyl demeton to cause death, 800 lb ai/A of mevinphos were needed before death occurred.

In practice, what would be the insecticide concentration in the soil from the accidental spillage of a 55-gallon drum of organophosphorus insecticide? A 55-gallon drum of the organophosphate malathion (an insecticide currently used in SOF and TAWC programs) contains 564 pounds of liquid having an active ingredient of weight of 536 pounds. If this much insecticide were uniformly distributed over a one-acre area to a depth of six inches, it would result in concentration of 266 ppm. If distribution were limited to an area of 1/2 acre, it would have a concentration in the soil of 536 ppm. The data from this report indicated that a concentration of 200 ppm (400 lb ai/A) of an organophosphate insecticide resulted in moderate to heavy plant damage, while a concentration of 400 ppm (800 lb ai/A) was lethal to the plants. All this presupposes that plants were the spill would have occurred. What happens to seed germination and/or seedling development? Scopes (4) noted that a concentration of 250 ppm of the organophosphorus insecticides thionazin or phorate significantly reduced germination and seedling development of sugar beets and various weed species. Thus, it seems feasible to suggest that a decontaminant is required in spillage areas. It should be recognized that decontamination of organophosphorus insecticides may be just as phytotoxic; nevertheless, decontamination would significantly reduce animal toxicity. This would be essential in avoiding detrimental levels of insecticide entering into the aquatic system.

All of the plants used in this study were approximately the same age, and because of seeding rate, all pots exhibited the same approximate amount of surface vegetation. The data does not suggest that the growth characteristics of the plant (e.g., monocot versus dicot) influenced the behavior of the plant to the insecticide. Corn and sorghum had essentially the same type of roots, were of the same age and height, yet responded in a completely different manner to the same insecticide. The data suggest that the mode of action of the organophosphorus insecticides in injury plants may not be a direct biochemical reaction (i.e., directly interfering with an enzymatic system) but rather a physical reaction based on the characteristic of whether the plant cell is susceptible or resistant to physical disruption.

REFERENCES

1. Wolverton, B. C., W. J. Wallace, A. L. Young, and D. D. Harrison. Studies on the Systemic Uptake of Toxic Phosphorus Esters by Plants--Morphological Effects of Foliar A-plications of the Organophosphorus Insecticides Mevinphos and Methyl Demeton on Selected Plant Species. AFATL-TR-69-116, Eglin AFB, Florida, September 1969.

2. Clore, W. J., W. E. Westlake, K. Walker, and V. R. Boswell. Residual Effects of Soil Insecticides on Crop Plants. Washington State University, Washington, Agr. Expt. Stat. Bulletin 627. 1961.

3. Boswell, V. R., W. J. Clore, B. B. Pepper, C. B. Taylor, P. M. Gilmer, and R. L. Carter. Effects of Certain Insecticides in Soil on Crop Plants. USDA Bulletin 1121. 1955.

4. Scopes, N. E. A. "Some Quantitative Effects of Soil-Applied Organophosphorus Insecticides on Crop Growth." Plant Path. 18:10-15. 1969.

5. MacPhee, A. W., D. Chisholm, and C. R. MacEachern. "The Persistence of Certain Pesticides in the Soil and Their Effect on Crop Yields." Can. J. Soil Sci. 40:59-62. 1960.

6. Edwards, C. A. "Insecticide Residues in Soils." Residue Reviews 13:83-132. 1966.

7. American Chemical Society. "Cleaning our Environment--The Chemical Basis for Action." A Report by the Subcommittee on Environmental Improvement, Committee on Chemistry and Public Affairs. Washington, D. C. 1969.

8. Lichtenstein, E. P., and K. R. Schulz. "Persistence of Some Chlorinated Hydrocarbon Insecticides as Influenced by Soil Types, Rate of Application and Temperature." J. Econ. Entomol. 52:124-131. 1959.

9. Getzin, L. W., and R. K. Chapman. Effects of Soils upon the Uptake of Systemic Insecticides by Plants. J. Econ. Entomol. 52:1160-1165. 1959.

10. Heath, D. F. Organophosphorus Poisons--Anticholinesterases and Related Compounds. Pergamon Press, New York. 1961.

11. Hall, W. C. "Morphological and Physiological Responses of Carnation and Tomato to Organic Phosphorus Insecticides and Inorganic Soil Phosphorus." Plant Physiol. 26:502-524. 1951.

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13. ABSTRACT

Data relating the tolerance of agronomic plants to soils contaminated with high concentrations of organophosphorus insecticides may emphasize the need for decontaminating soils following accidental spillage. The insecticides 2-carbomethoxyl-1-methylvinyl dimethyl phosphate (mevinphos) and a mixture of the two isomers 0,0-dimethyl S-[2-(ethylthio) ethyl] phosphorothioate and 0,0-dimethyl 0-[2-(ethylthio)ethyl] phosphorothioate (methyl demeton) were soil applied to 15 economically important plants at the rate of 100, 200, 400, and 800 pounds active ingredient per acre. The separate statistical analysis of the several days (1, 3, 7, and 10) on which measurements (damage ratings) were taken indicated that the effects of damage were clearly manifested by the seventh day. By the seventh day the average observed damage caused by mevinphos (all plants averaged) was slight to moderate while damage caused by methyl demeton was moderate to heavy. The 15 plant species could be divided into eight groups on the basis of similar phytotoxic responses to the insecticides. The most susceptible plants to soil drench applications were oats, wheat, collards, tomatoes, and sorghum.

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